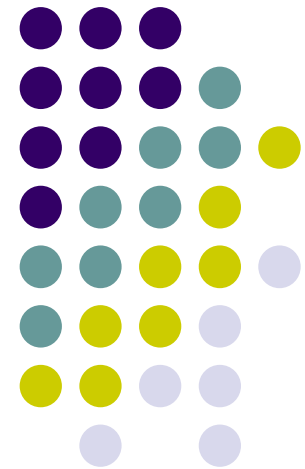


# IRC data & imaging toolkit

Yoshifusa Ita  
& IRC team



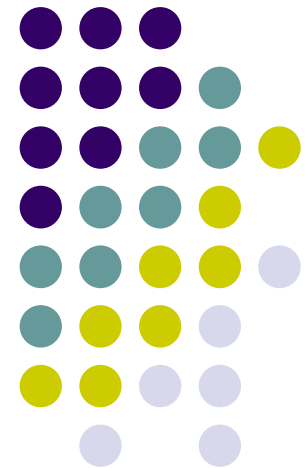


# Outline

- Part 1
  - IRC data structure
  - Characteristics and known problems
  - Imaging/Spectroscopic toolkit
  - This part is common to both imaging and spectroscopic data
- Part 2
  - IRC imaging data reduction toolkit
  - Things that are not included yet

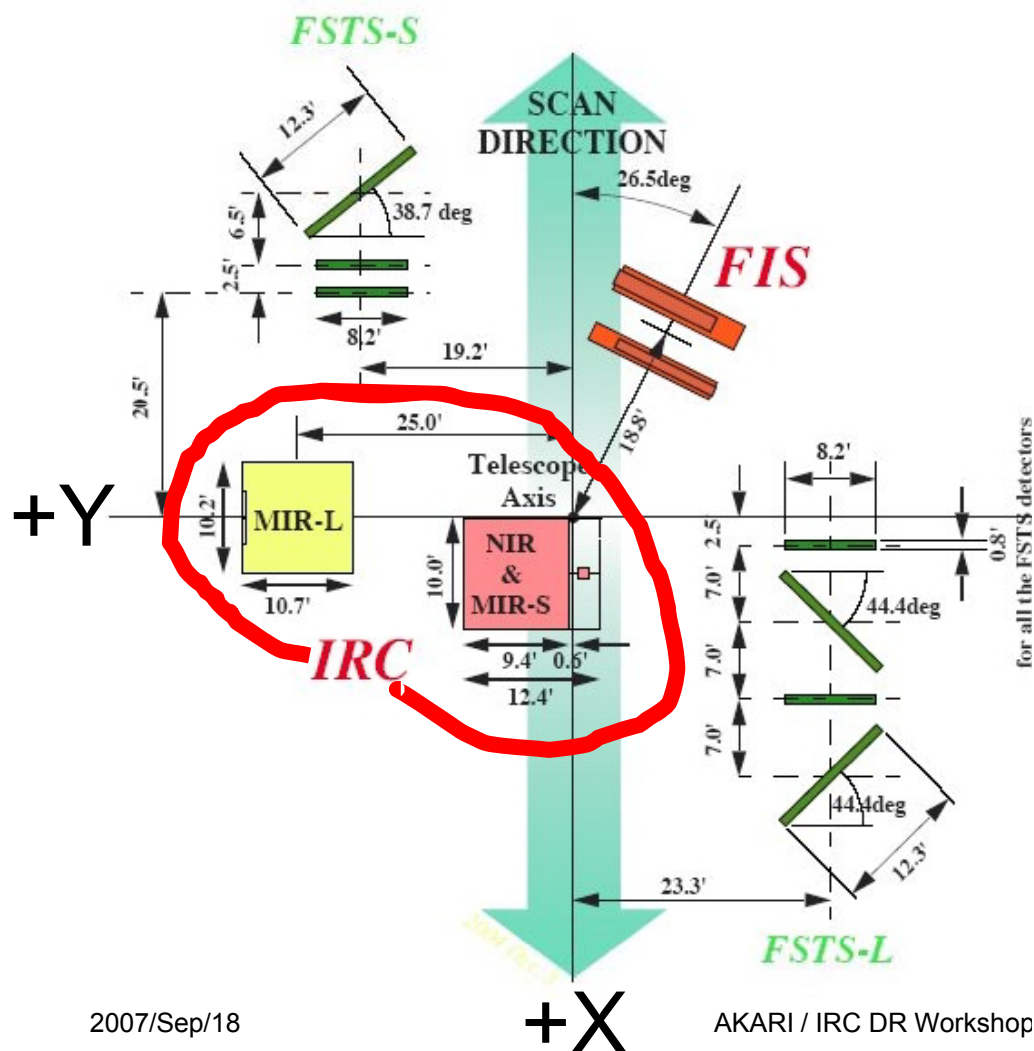
# Part 1: IRC data

- Focal plane layout
- Observational sequence
- Structure of IRC fits files
- Current status and characteristics/problems





# Focal-plane layout

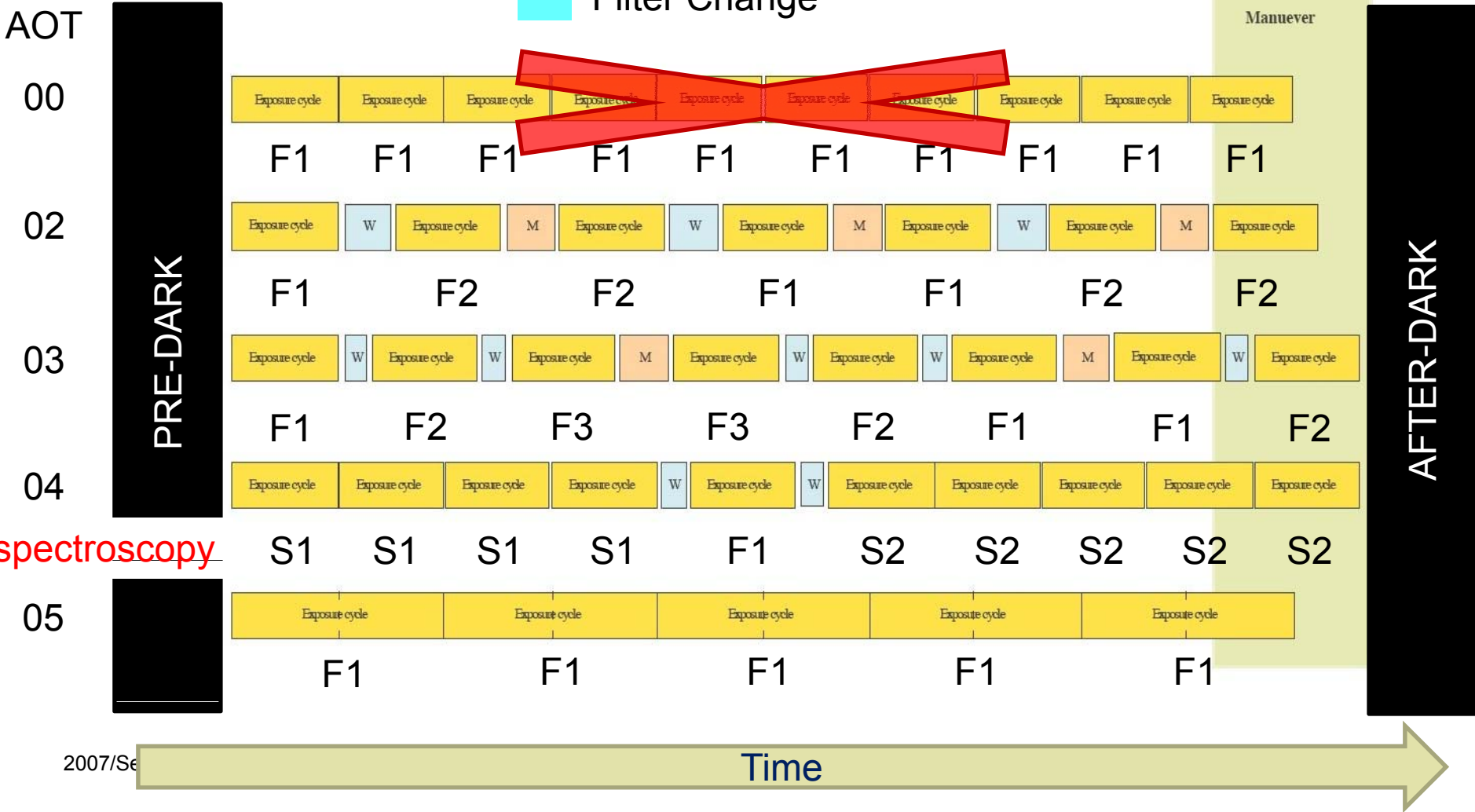


- The IRC consists of 3 detectors.
  - NIR (InSb, 512x412)
    - 2-5 um
    - N2,N3,N4 & NP,NG
  - MIR-S (Si:As, 256x256)
    - 5-13 um
    - S7,S9W,S11 & SG1,SG2
  - MIR-L (Si:As, 256x256)
    - 12-26 um
    - L15,L18W,L24 & LG2
- Each camera is equipped with three filters and two dispersion elements.
- NIR and MIR-S observe the same sky but **MIR-L and NIR&MIR-S do not observe the same sky.**

# Observation sequence in one pointing

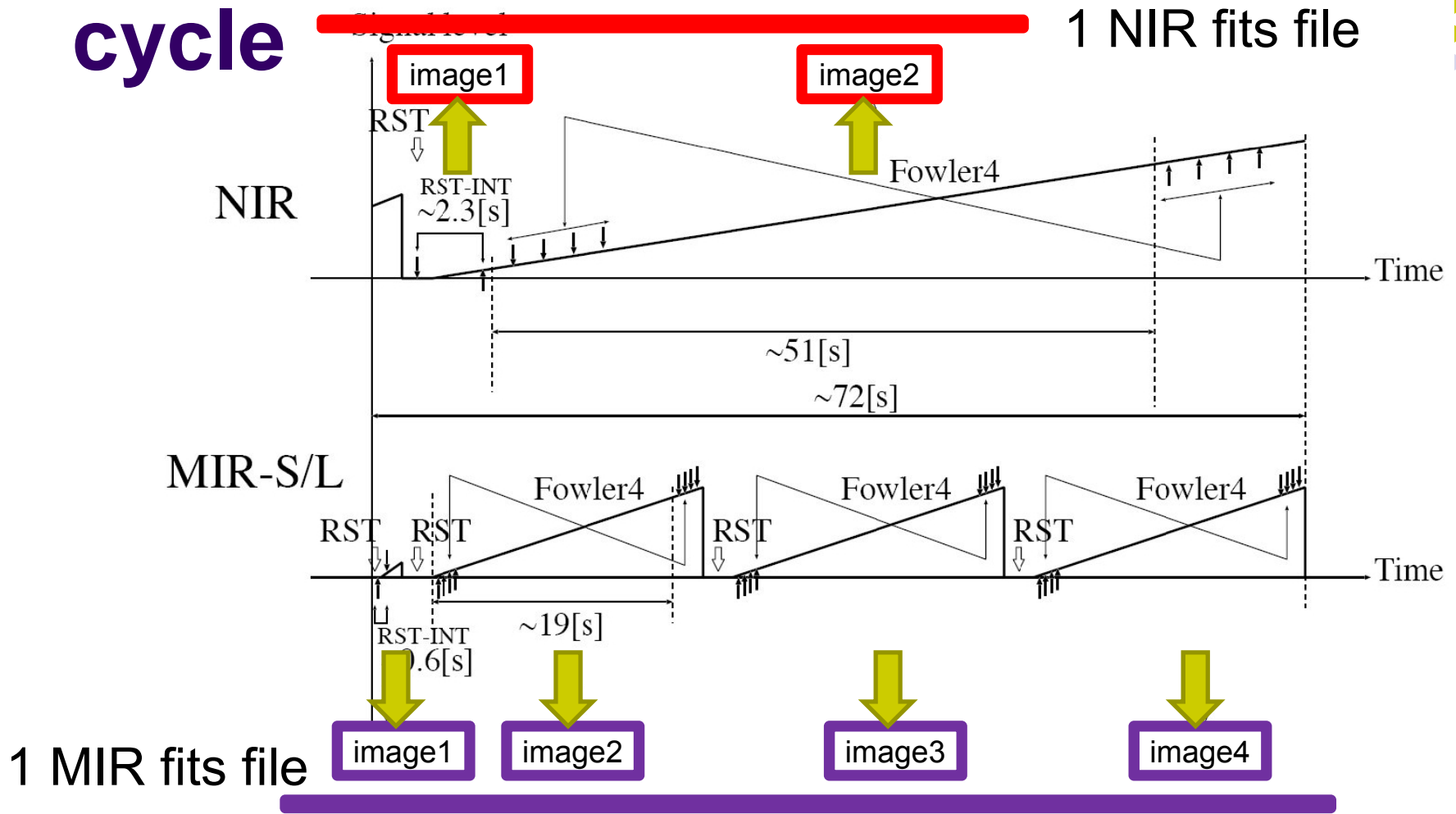


- Exposure Cycle
- Dithering
- Filter Change



spectroscopy

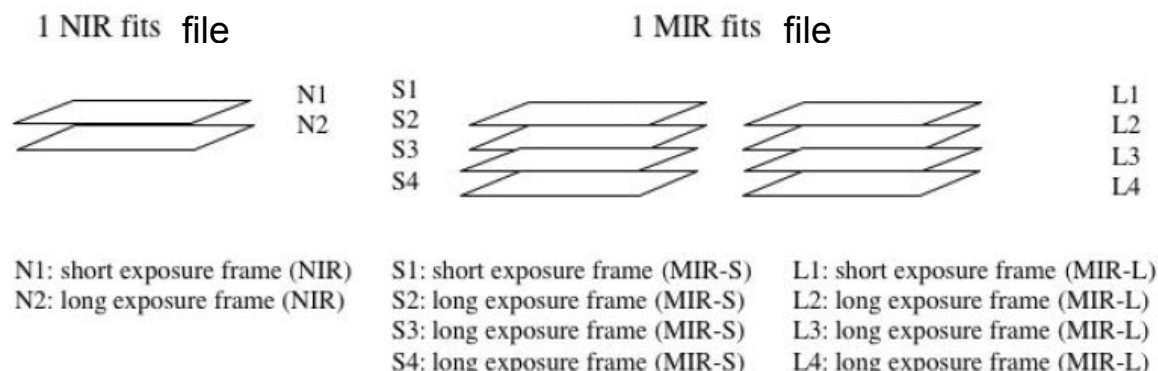
# operation of one exposure cycle



- A pair of short and long exposures are carried out for the NIR camera while one short and three long exposures are carried out for the MIR detectors. RST indicates a reset of the detectors.



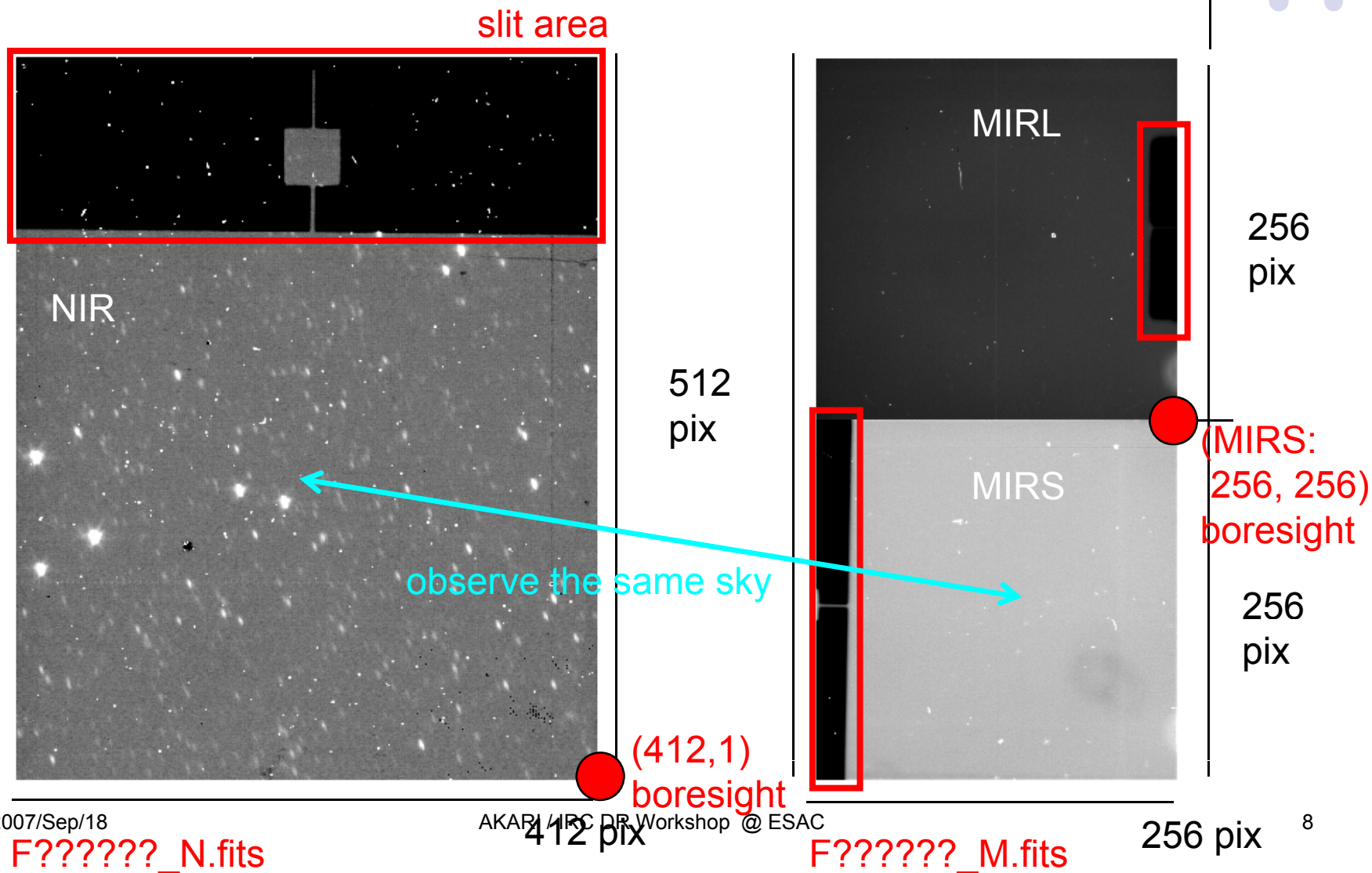
# Structure of IRC fits files



- **The IRC FITS data is not a usual 2D one.** A raw data FITS file is created for each Exposure Cycle during a pointing for the NIR and combined MIR-S/MIR-L channels. (i.e. 1 NIR FITS file and 1 MIR FIT file = 2 FITS files per Exposure Cycle). The filename format is given as F\*\*\*\*\* N.fits or F\*\*\*\*\* M.fits, where \*\*\*\*\* is a distinct incremental reference number.
- A NIR raw fits data file is a data cube containing 2 images within it, corresponding to one short and one long exposure.
- Each MIR raw FITS file contains 4 images within it (one short and three long exposures) for both the MIR-S and MIR-L channels respectively making a total of 8 frames per MIR FITS file per Exposure Cycle.



# What you will get = rawdata





# Difference from the familiar fits files (summary)



- **3-dimensional**
  - 1 NIR fits file contains:
    - 1 short exposure image
    - 1 long exposure image
  - 1 MIRS fits file contains:
    - 1 short exposure image for MIRS and MIRL
    - 3 long exposure image for MIRS and MIRL
- **MIRS and MIRL do not observe the same sky, but they are stored in one fits file.**



# What you will get = rawdata

- Your data can be obtained from:
  - <http://darts.isas.jaxa.jp/astro/akari/getData.html>
- The data are encrypted with GPG
  - e.g.: AKARI\_IRC\_2200007\_001.tar.gpg
- Decrypted data are stored in a tar ball.
  - e.g.: AKARI\_IRC\_2200007\_001.tar
- Unpack the tarball
  - -> next slide



# inside the tar ball

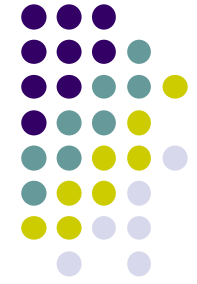
- README and a directory(TargetID.subID)
  - README
    - observation summary, etc.
    - Please read through this file.
  - TargetID.subID/ e.g.: 3080003.1
    - rawdata
      - contains raw data
        - F?????????\_[N|M].fits: raw data
        - \*.lst: list of data files observed with each filter/grism
        - World Coordinate System Parameters are given in the fits header
    - irc\_q1
      - contains processed data with standard toolkits with standard options.
      - only for quick look purpose.
    - see README for details of the text files inside the two directories.

# Very important Fits Header Keyword = WCSROOT

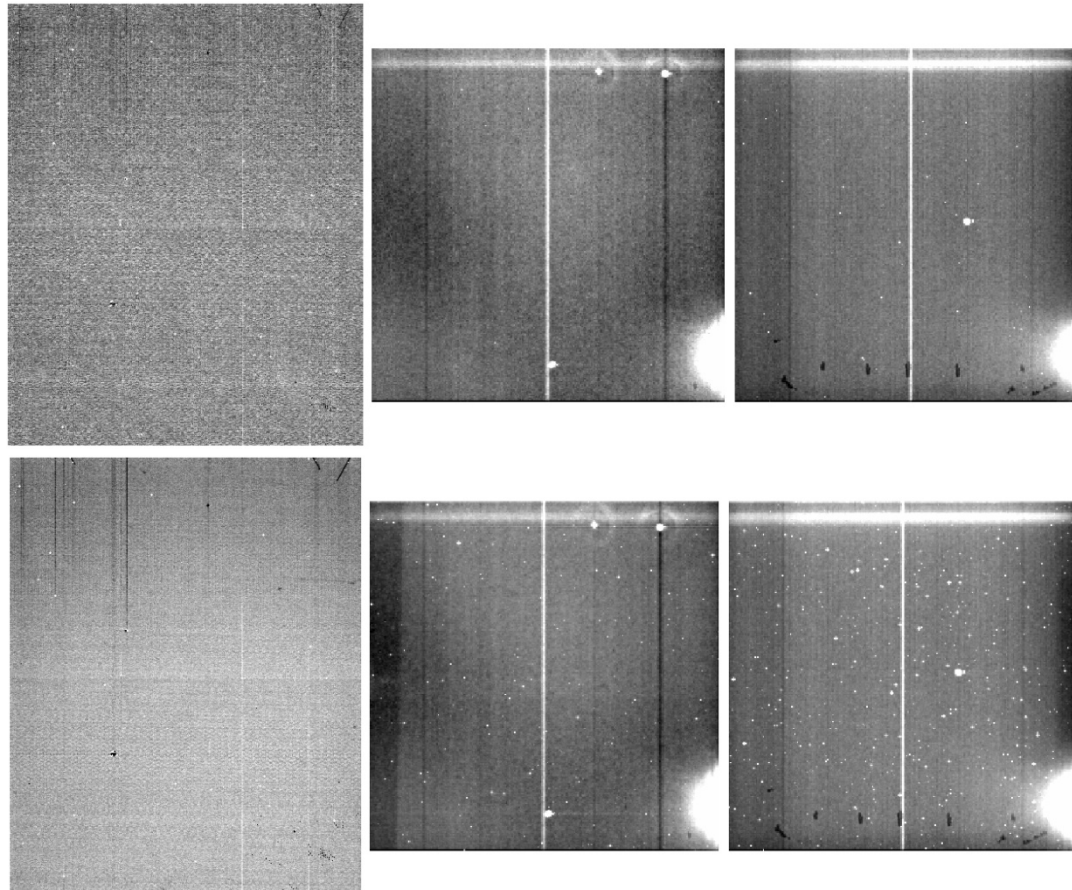


- WCSROOT
  - AOCS (Default)
    - on the basis of Attitude and Orbit Control System
    - Accuracy is better than 30 arcsec
      - Depends on ecliptic latitude of target because of aberration
  - 2MASS (After using toolkits)
    - on the basis of 2MASS coordinates
    - matching 2MASS sources with point sources detected
    - Accuracy is better than a few arcsec, and in most cases, better than 1 arcsec
      - Depends on how match stars were matched.

# Current status and characteristics/problems (1)



- The number of hot pixels are increasing



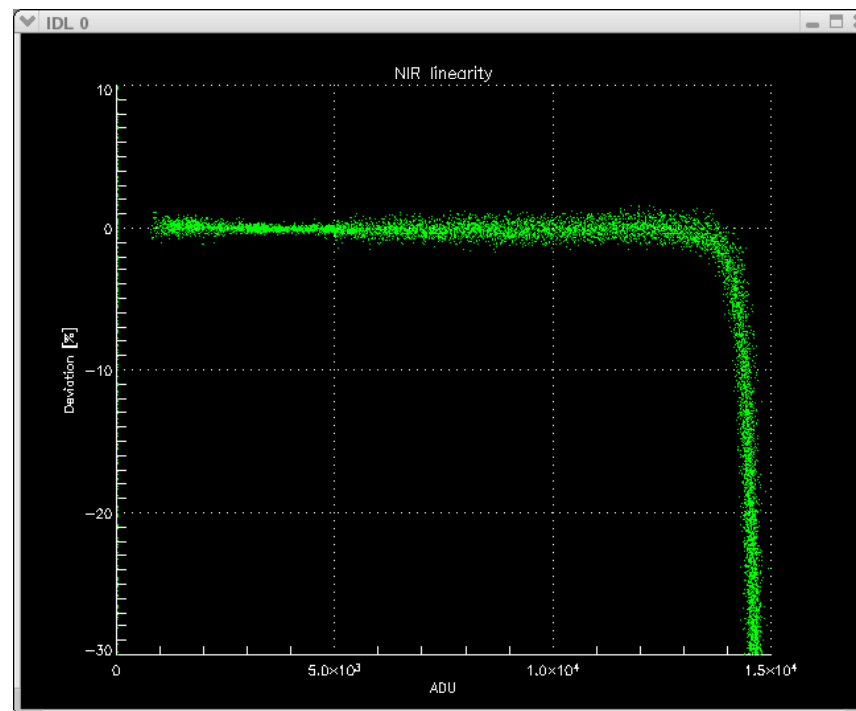
PV phase  
(April, 2006)  
dark image

4 months Later  
(August, 2006)  
dark image

# Current status and characteristics/problems (2)



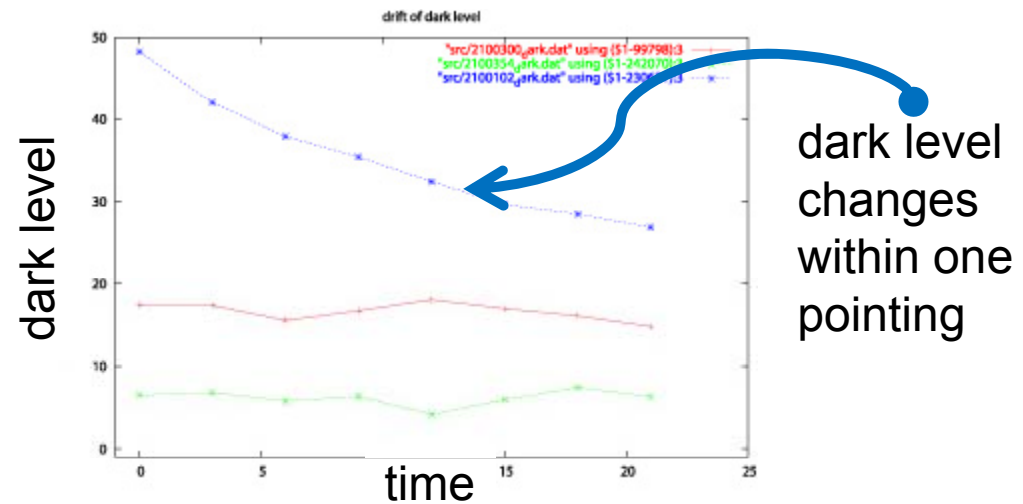
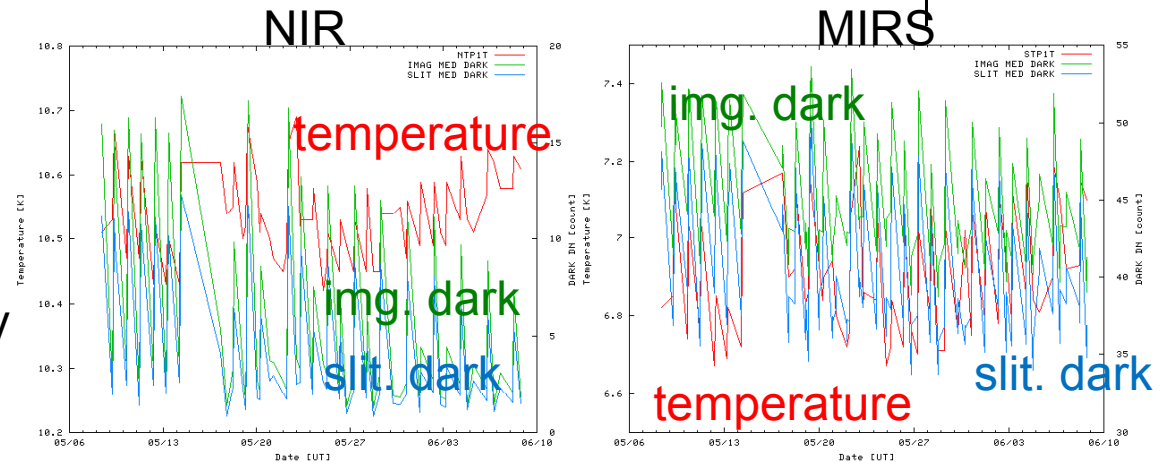
- Detector linearity
  - measured with IRC installed in the laboratory and in flight like configuration
  - measurements were made with calibration lamp that illuminates detector and an increasing range of integration times
  - after the correction, the deviation from the ideal linear curve is better than 5% at the DN of 12000 and 30000 in NIR and MIR, respectively



# Current status and characteristics/problems (3)



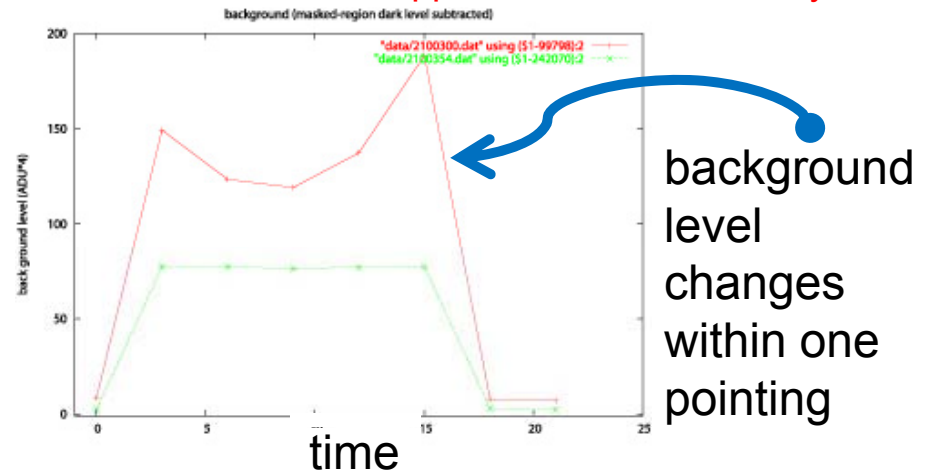
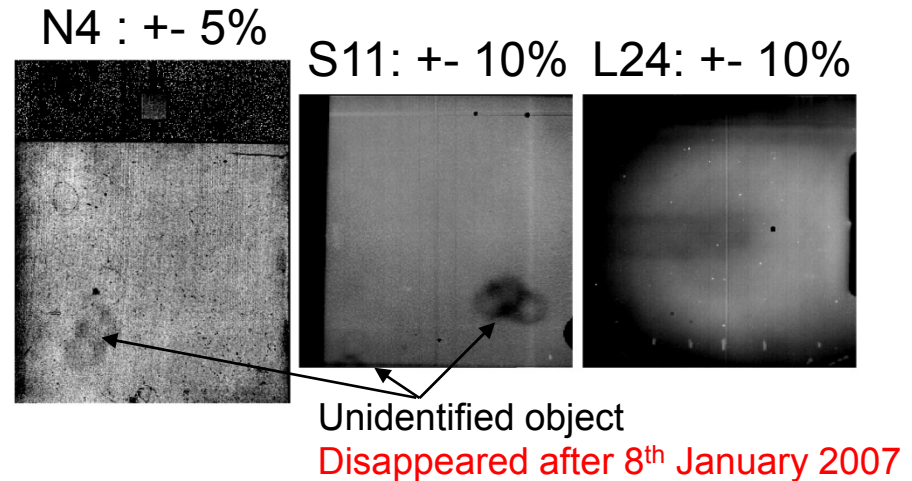
- Dark and/or Bias stability
  - dark level is NOT stable during 1 pointing.
  - super-dark images were made with pre-dark data taken in LMC survey. They are “shifted”, i.e., add/subtract a certain constant, by checking slit area in each image, and then subtracted.
  - NIR: no apparent correlation with detector temperature
  - MIR: weak correlation with detector temperature
  - dark level is very high after passing SAA



# Current status and characteristics/problems (4)



- Flat field
  - NIR
    - NEP survey data
    - S/N : about 10
  - MIR
    - NEP survey data
    - S/N : more than 100
- Stray light
  - present in all detectors
  - unexpected high background probably due to external (Earth) light, which is not uniform over the FOV (MIR-L)
  - flat-field are affected
  - observation of diffuse background will suffer

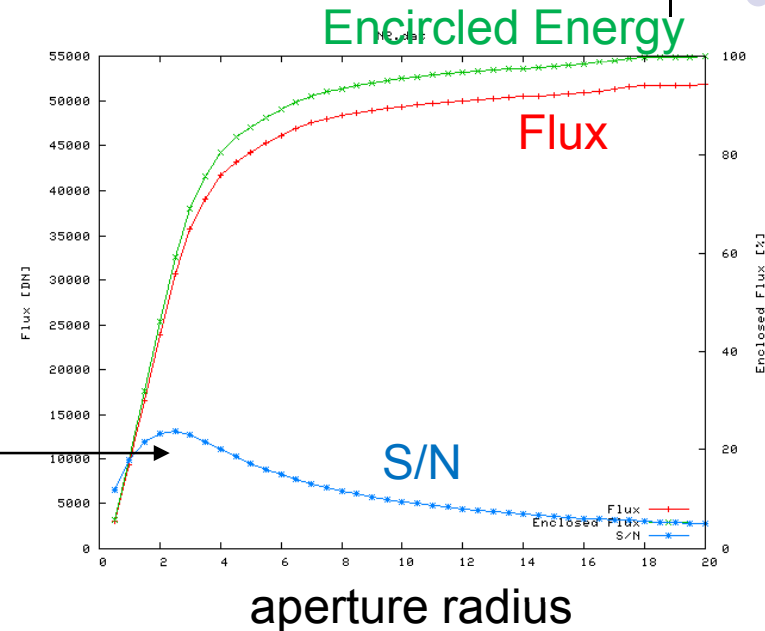




# Current status and characteristics/problems (5)



- Aperture Correction
  - IRC flux calibration were made by observing standard stars (point source)
  - we assume that all flux are come into certain radii (10 and 7.5 pixels for NIR and MIR).
  - these radii are large compared to S/N optimal apertures
  - the amount of flux enclosed in these radii is still UNKNOWN (i.e., flux calibration for diffuse source is still unknown)
  - aperture corrections must be applied when using different apertures
  - we will provide aperture corrections, but observers are encouraged to see their own curves-of-growth because the PSF differs from pointing to pointing



$$Signal = Const * EE(r_{aperture})$$

$$Noise = \sqrt{\sum_i^{N_{pixel}} noise_i^2} = \sqrt{N_{pixel}} * noise_{pixel}$$

$$N_{pixel} = \pi * r_{aperture}^2$$

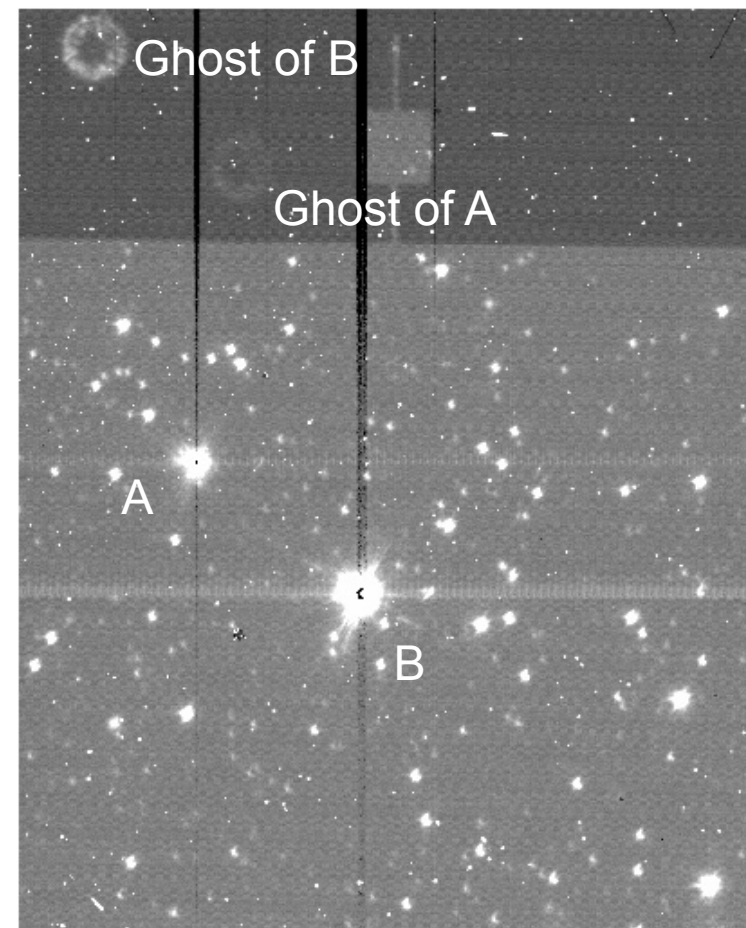
$$\frac{Signal}{Noise} = \frac{Const}{\sqrt{\pi} noise_{pixel}} * \frac{EE(r_{aperture})}{r_{aperture}}$$

i.e.,  $S/N \propto EE(r)/r$

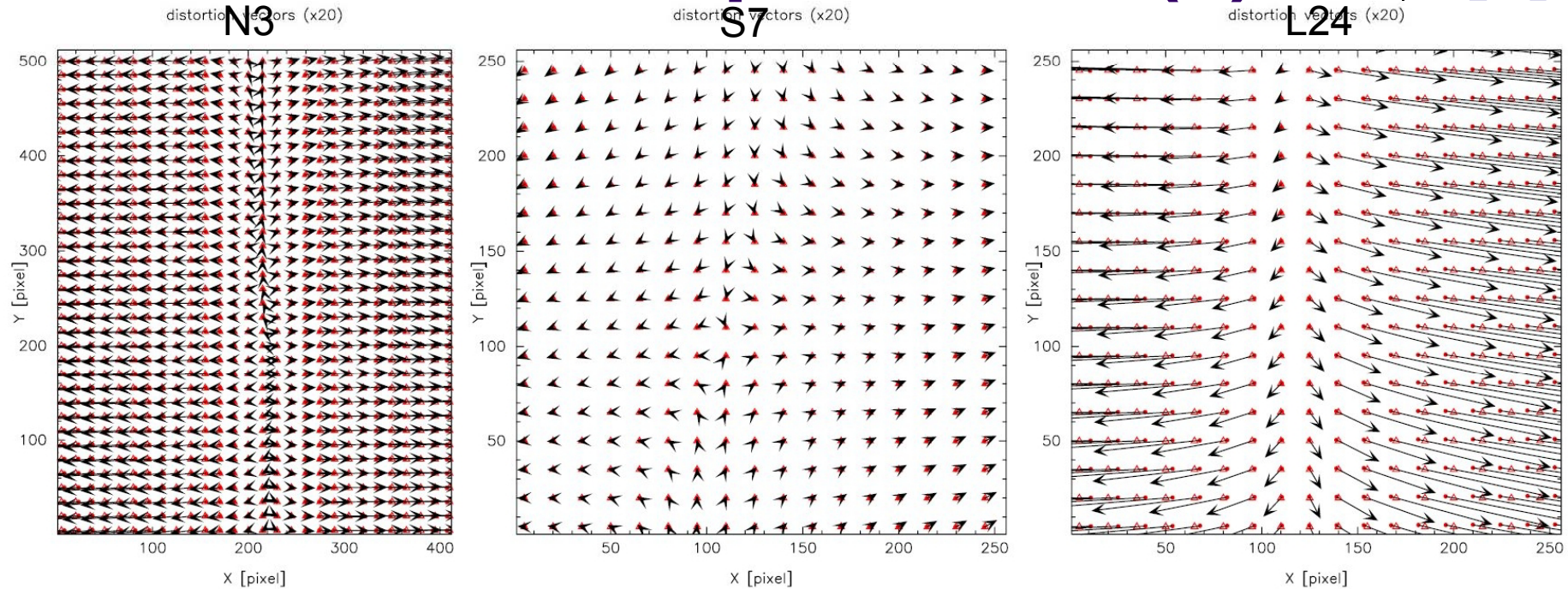
# Current status and characteristics/problems (6)



- Ghost in slit-area
  - NG slit-spectroscopic data would be damaged if bright stars were present in the imaging area.
  - Details → Ohyama-san's presentation.



# Current status and characteristics/problems (7)

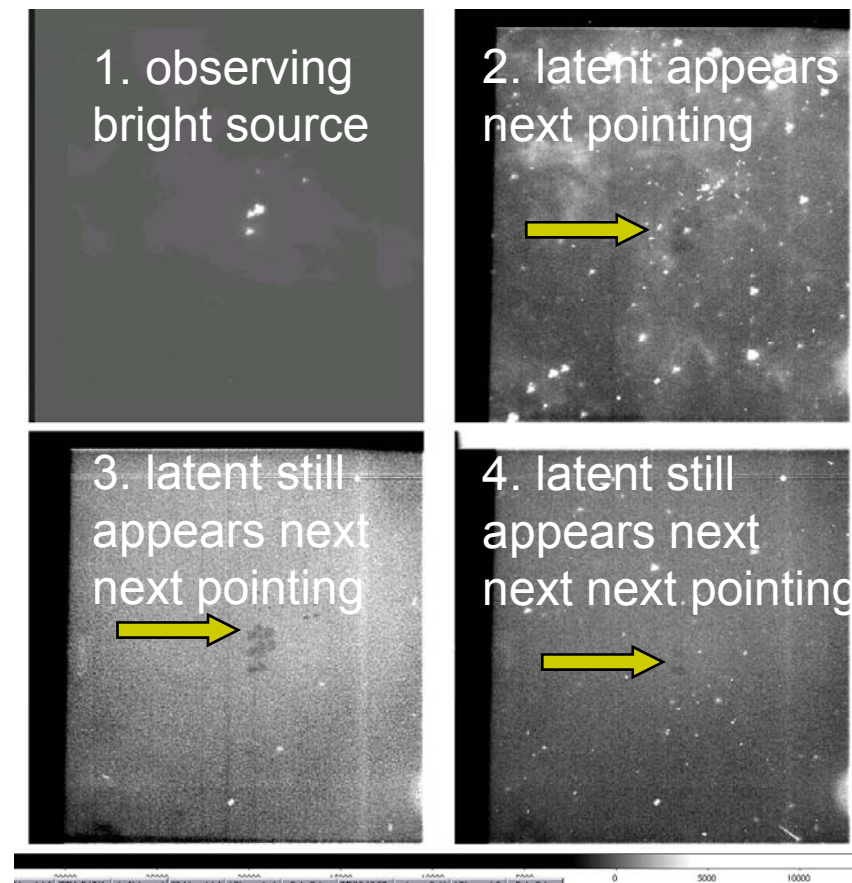


- Aspect ratio and Distortion term
  - The deviation from an ideal lattice is up to 2, 0.6, and 16 pixels at the edge for NIR, MIRS and MIRL, respectively. There is little difference with filters among a detector.
  - Main contribution of the deviation comes from aspect ratio disorder.
  - Distortion term (non-linear term) is very small, but present in MIR-L detector.
  - Toolkit corrects aspect ratios, but not distortion.
  - the resultant pixel scales of NIR, MIRS, and MIRL become 1.446, 2.340, and 2.384 arcsec/pixel, respectively. All detectors have wide field of views of 10'x10.

# Current status and characteristics/problems (8)



- Latent in MIR-S&L
  - Flat changes after observing very bright stars.
  - A few % decrease
  - Last for several (up to 8) hours



# Imaging/Spectroscopy toolkits

## Common Principles



- Please use our toolkits, not yours
  - our toolkits includes calibration data
    - Imaging
      - linearity, flat, etc.
    - Spectroscopy
      - flux calibration, flat, etc.
  - calibration data may be updated in the future
- Please send your new tool to helpdesk.
  - we will test it, and maybe ask you to allow us to distribute.



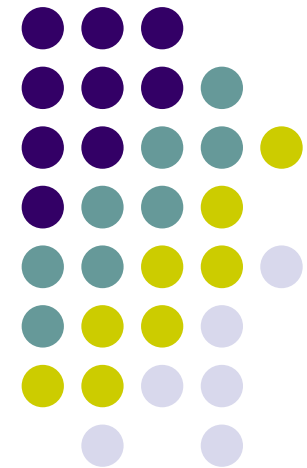
# Toolkits: Where to get?

- Imaging/Spectroscopic data reduction toolkits can be downloaded from:
  - <http://www.ir.isas.jaxa.jp/ASTRO-F/Observation/DataReduction/IRC/>
  - Manuals, Tips, and FAQs are also there.
- For Help
  - send emails to helpdesk: *iris\_help@ir.isas.jaxa.jp*
  - Do not forget to tell us your TargetID.
  - Please read the manual and FAQs again before sending emails.

# Part 2: IRC imaging toolkit

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- Requirements
- Outline
- What you will get
- Things not included yet





# Requirements

- Unix (Linux, BSD, OSX, Solaris)
  - Perl
  - GCC3.0 or later
  - IRAF version 2.12.2 or later
  - curl (for WCS calculation on Solaris)
- 
- Imaging pipeline may work on Intel-Mac PC
  - Does not work on Windows PC





# Outline of pipeline

- **Red Box** (pre-pipeline processor)
    - header formatting
    - **Make observing log**
  - **Green Box** (pipeline processor)
    - instrumental signature correction
      - wraparound, fowler/bit-shift renormalization
      - dark subtraction, linearization, flat fielding, distortion correction etc.
    - **Make Basic Data**
  - **Blue Box**
    - co-add dithered images (multi-pointing compliant)
    - **Make Post Basic Data**
- } prepipeline
- } pipeline

# What you get from the pipeline



- Basic Data
  - single image
  - The unit of resultant image is in [DN]
    - **absolute calibration is not applied**
    - [DN] depends only on exposure time, i.e., you can compare data among any AOTs and short/long exposure images by only considering the difference of exposure times.
    - a table to convert from [DN/sec] to [Jy] for each filter is supplied by Dr. Tanabe.
  - Calibrated:
    - linearization applied
    - dark subtracted (using super-dark or self-dark)
    - flat-fielding applied (using super-flat)
    - distortion corrected



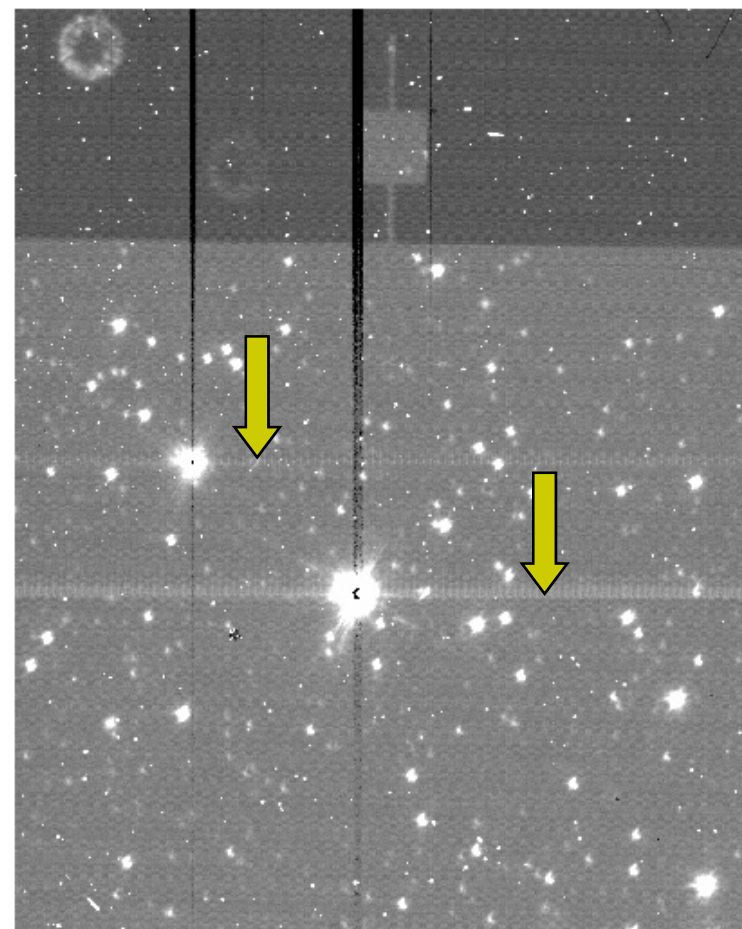
# What you get from the pipeline

- Post Basic Data
  - coadded image for each filter
  - Sometimes pipeline fails to coadd MIRL (L15, L18W, L24) images.
    - However, **there is a help tool** that uses MIRS shift/rotation to co-add MIRL images.
  - Basic WCS is supplied in the header by default
    - Pipeline can automatically match 2mass sources to improve accuracy by using a tool (**not applied by default. this is an option**).
    - sometimes the tool fails to match 2mass sources(L15, L18W, L24)
    - Accuracy is
      - Better than 30 arcsec after pipeline (WCSROOT=AOCS)
      - Depends on  $\beta$  because of **aberration**
      - Better than a few arcsec after matching 2mass sources (WCSROOT=2MASS)
      - Dependts on how many stars were matched



# Things not included yet (1)

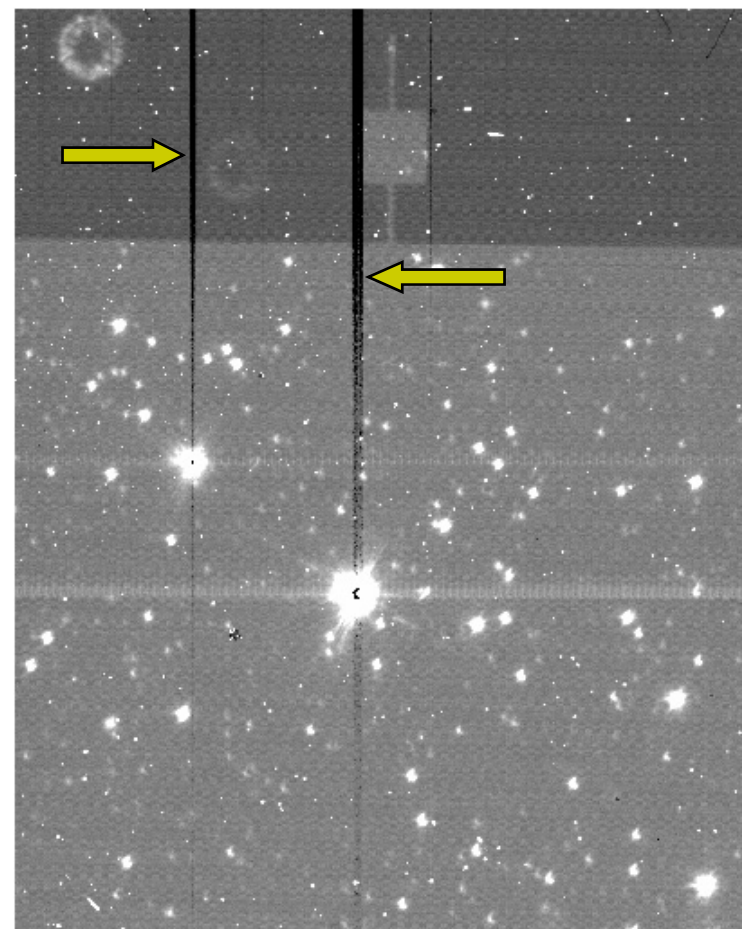
- Muxbleed
  - present in NIR
  - trail of bright pixels in read direction every 4<sup>th</sup> column





# Things not included yet (2)

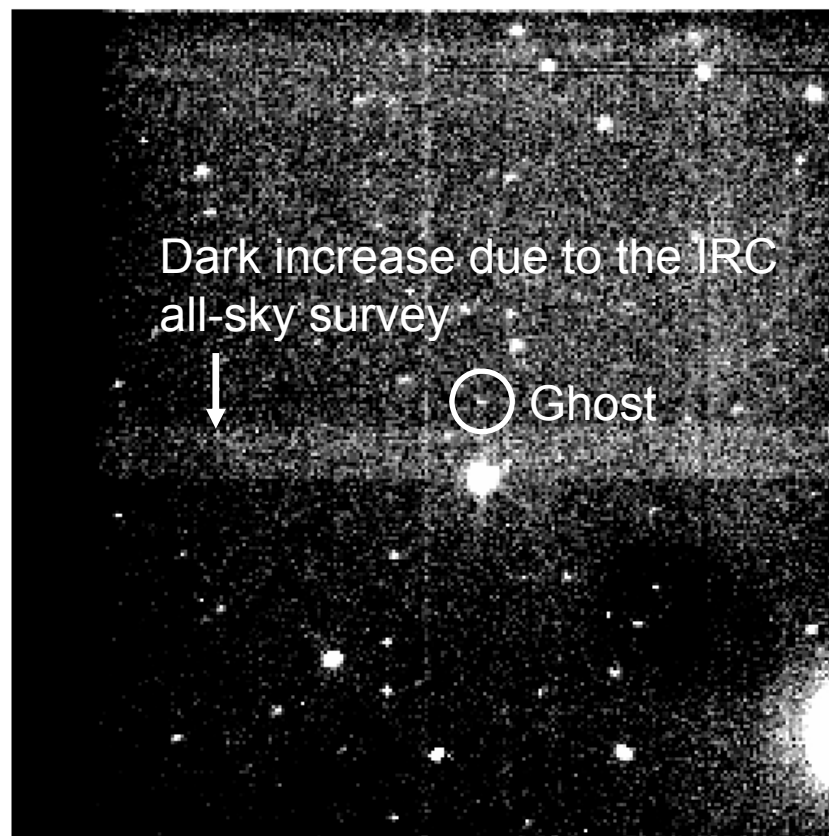
- Column Pulldown
  - present in NIR
  - a bright source results in a decrease of 20 – 60 DN in the entire column(s)





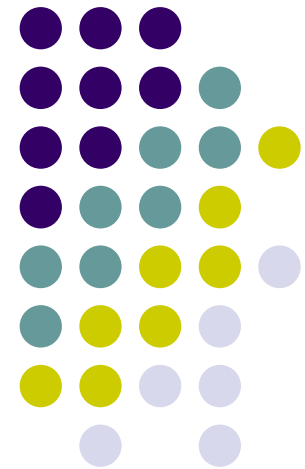
# Things not included yet (3)

- Ghost in imaging-area
  - present in all detectors
  - position and strength differ from detector to detector and also from filter to filter.
  - strongest (~ 4% of parent source) in S11
  - caused by internal reflections in beam splitter and also lenses.



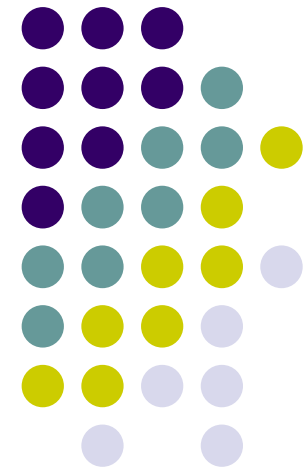
# End

Enjoy IRC data !!



# Appendix

what you will get from the pipeline  
&  
structure of pipeline





# What you get from the pipeline



- Other files (0)
  - **irclog**
    - created by prepipeline
    - observing log
  - **darklist.before**
    - created by prepipeline
    - a list that contains the name of dark images taken before observation.
    - required if you want to use selfdark image instead of super-dark

# What you get from the pipeline



- Other files (1)
  - F?????????\_[NSL]00[1-4].fits
    - created by prepipeline
    - split 3D raw fits files into usual 2D ones.
    - headers are overwritten
      - CPIX1&2
      - FILTER
    - almost equals to raw data except for dimension and headers.

# What you get from the pipeline



- Other files (2)
  - `ef*F?????????_[NSL]00[1-4].fits`
    - created by pipeline just before coadd process.
    - all things are calibrated
      - dark, flat, linearity, distortion, etc...
    - **Basic Data**



# What you get from the pipeline

- Other files (3)
  - **Sef\*F?????????\_[NSL]00[1-4].fits**
    - f\*F?????????\_[NSL]00[1-4].fits
      - 412x512 (256x256) : NIR (MIRS&L)
    - copy it to big frame
      - 1024x1024 (512x512) : NIR (MIRS&L)
  - **Sef\*F?????????\_[NSL]00[1-4].fits.coo.1**
    - result files of source detection
    - contains xy coordinate and arbitral brightness
  - **Sef\*F?????????\_[NSL]00[1-4].fits.shift**
    - result files of calcshift.cl
    - database file to correct shift and rotation

# What you get from the pipeline



- Other files (4)
  - **RSef\*F?????????\_[NSL]00[1-4].fits**
    - rotation and shift corrected Sf\*\* .fits images
  - **ASef\*F?????????\_[NSL]00[1-4].fits**
    - Sky adjusted Rsef\* .fits images
    - These files are actually combined to make the final coadded images.



# What you get from the pipeline

- Other files (5)
  - **long(short)\_exp.input**
    - list file containing the name of pair files for long/short exposure.
  - **pair000?\_[filtername].list**
    - list file containing the name of files taken by filtername filter.
  - **pair000?\_[filtername].list\_long(short)**
    - split pair000?\_[filtername].list according to exposure time (long/short).
  - **pair000?\_[filtername].list\_long(short).shift & shift.0**
    - contains dx[pix], dy[pix], dr[deg] (relative to the “first” image), and # of stars matched to calculate dx, dy, dr.
  - **pair000?\_[filtername].list\_long(short).combine**
    - contains filename that were combined to create coadded images. Note that images with outlier sky levels were excluded from the coaddition.

# What you get from the pipeline



- Other files (6)
  - files in logs
    - **calcshift.log**
      - log of calcshift.cl
      - see for the rms of x and y linear fit results.
    - **skypair000?\_[filtername].list\_(long/short)**
      - log file of adjust\_sky.cl that shows mean, median, mode of the sky level, and sigma.
      - any files with outlier sky level will be excluded from the combine process.

# What you get from the pipeline



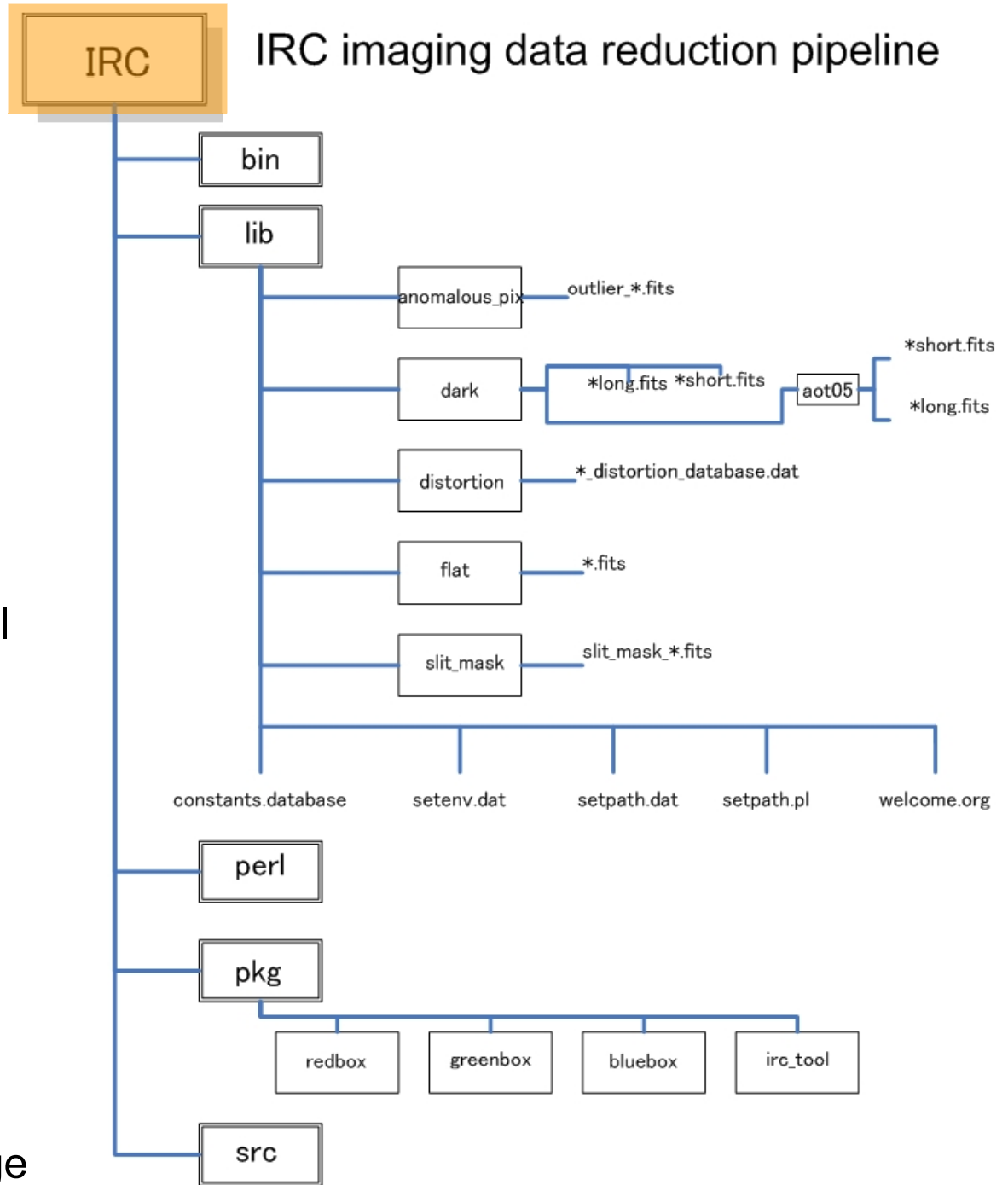
- Other files (7)
  - files in stacked\_IM
    - Objectname\_[filtername]\_(long/short).fits
      - result
      - post basic data
    - pObjectname\_[filtername]\_(long/short).fits
      - NCOMBINE – values in each pixel = exposure map
    - sigmaObjectname\_[filtername]\_(long/short).fits
      - standard deviation of each pixel



# Structure of pipeline(1)

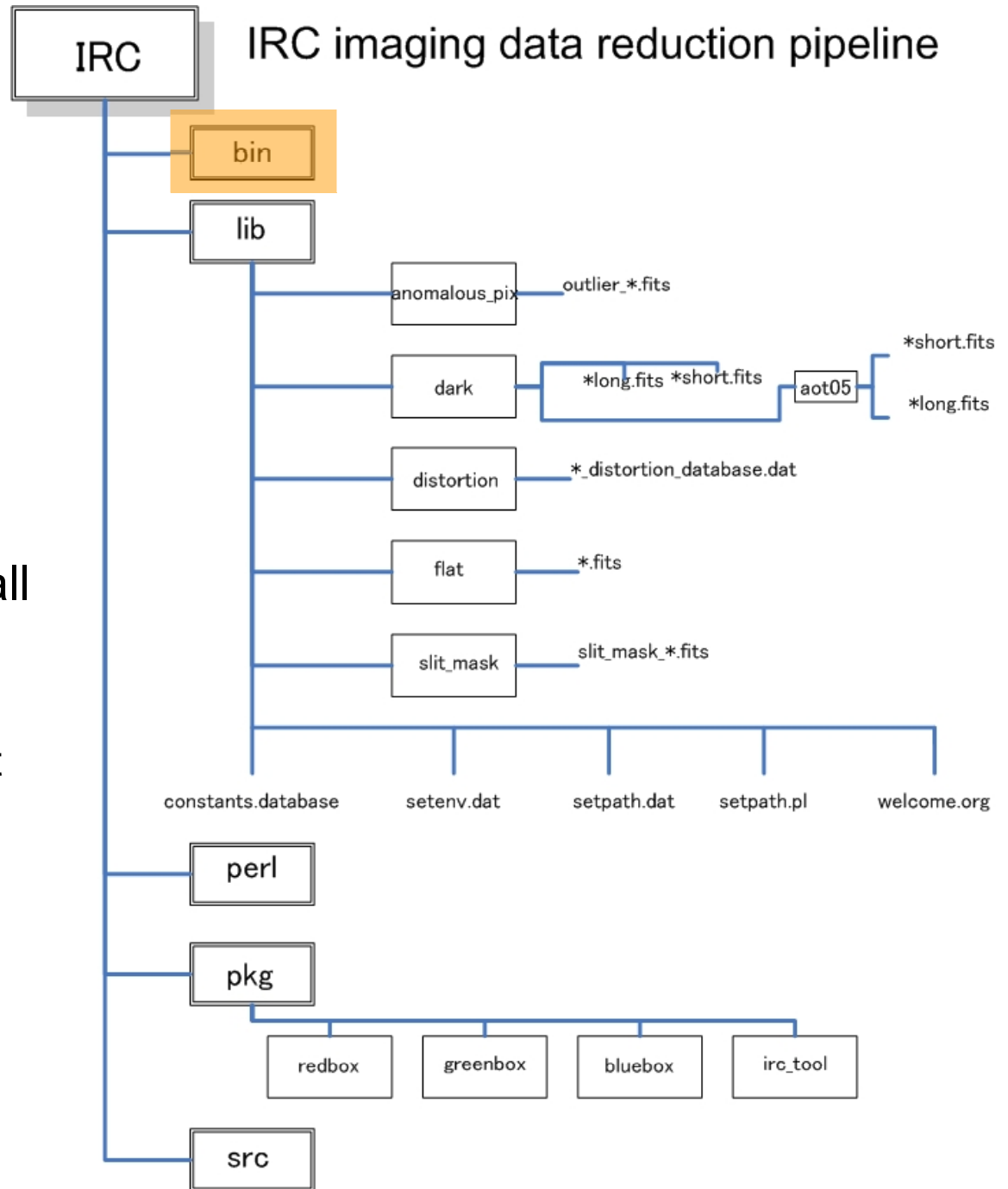
- irc
  - irc.cl
    - package root
  - load.cl
    - iraf packages preloaded in irc.cl
  - pipeline.cl
    - pipeline
  - prepipeline.cl
    - prepipeline
  - unlearn\_all.cl
    - unlearn iraf parameters
  - welcome.txt
    - welcome message

2007/Sep/18



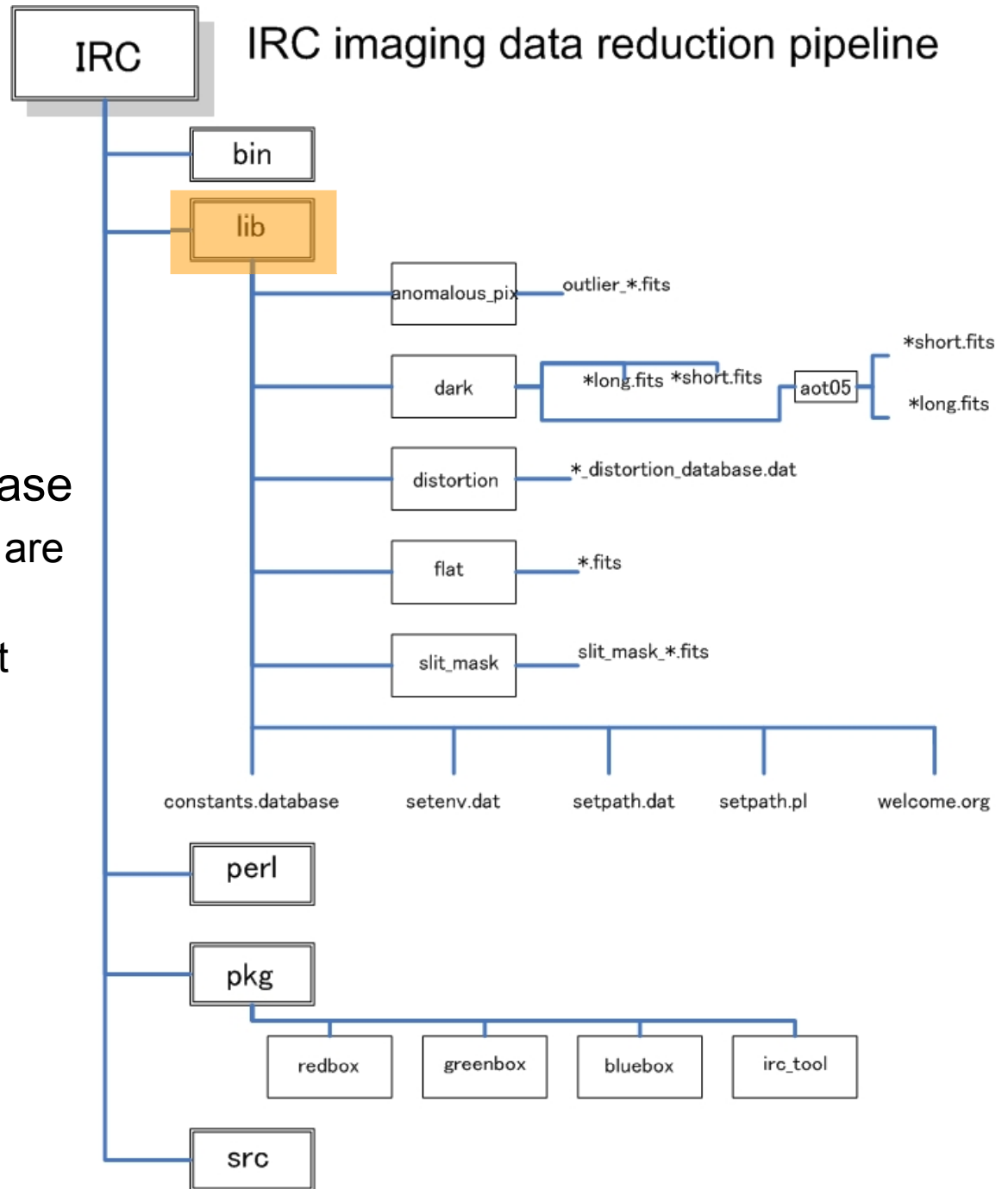
# Structure of pipeline(2)

- binary
  - binary files
    - convert2mass
      - used in putwcs
    - convert2mass\_all
      - used in putwcs
    - lonesome
      - used in calcshift
    - mkflatpair
      - used in flat
    - mkpair
      - used in coadd



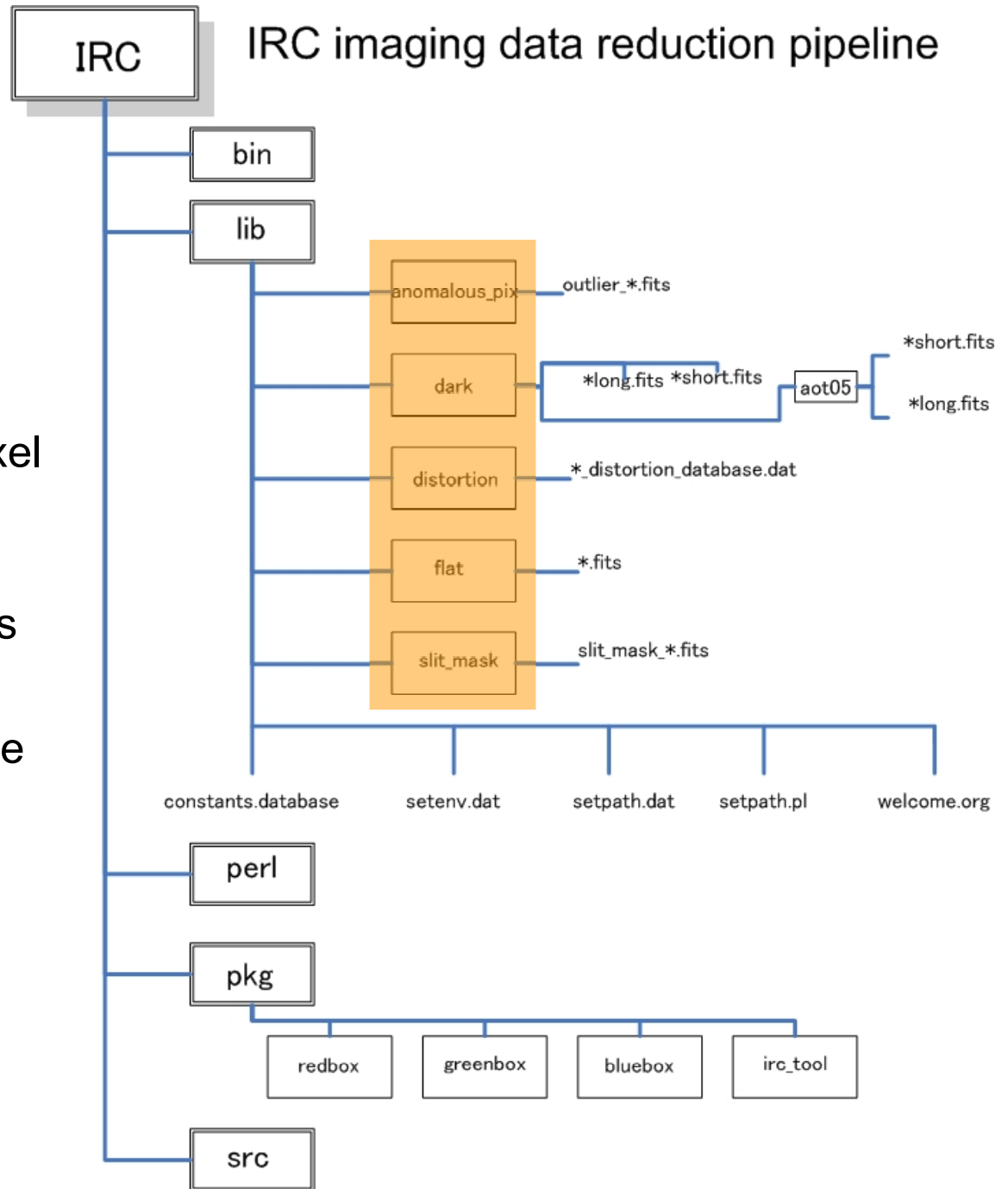
# Structure of pipeline(3)

- lib
  - library files
    - constants.database
      - all irc constants are in this file.
      - you can edit it at your own risk
    - setenv.dat
    - setpath.dat
    - setpath.pl
    - welcome.org



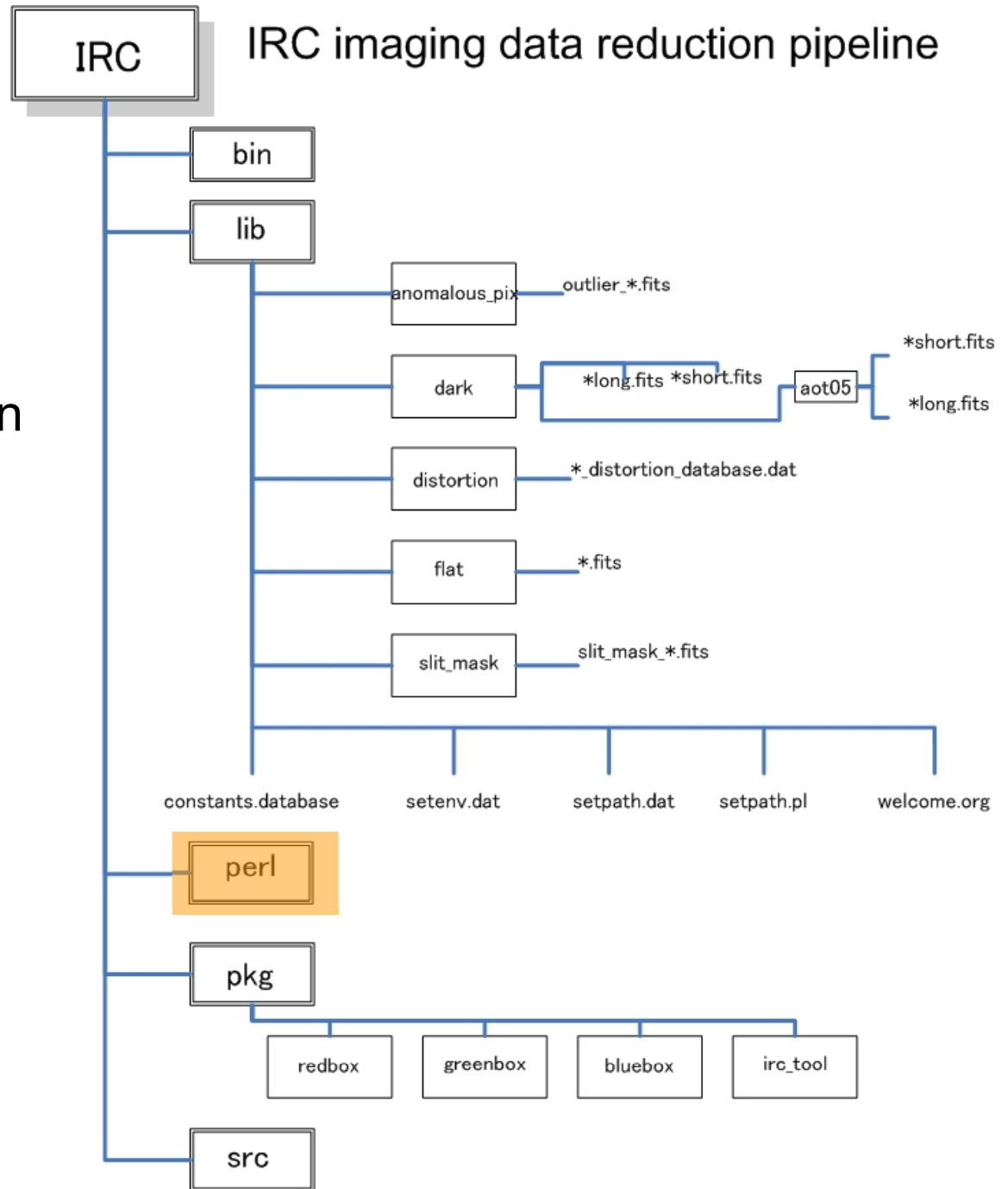
# Structure of pipeline(4)

- lib - subdirectories
  - anomalous\_pix
    - known hot/bad pixel map images
  - dark
    - super-dark images
  - distortion
    - distortion database
  - flat
    - super-flat images
  - slit\_mask
    - slit-area mask images



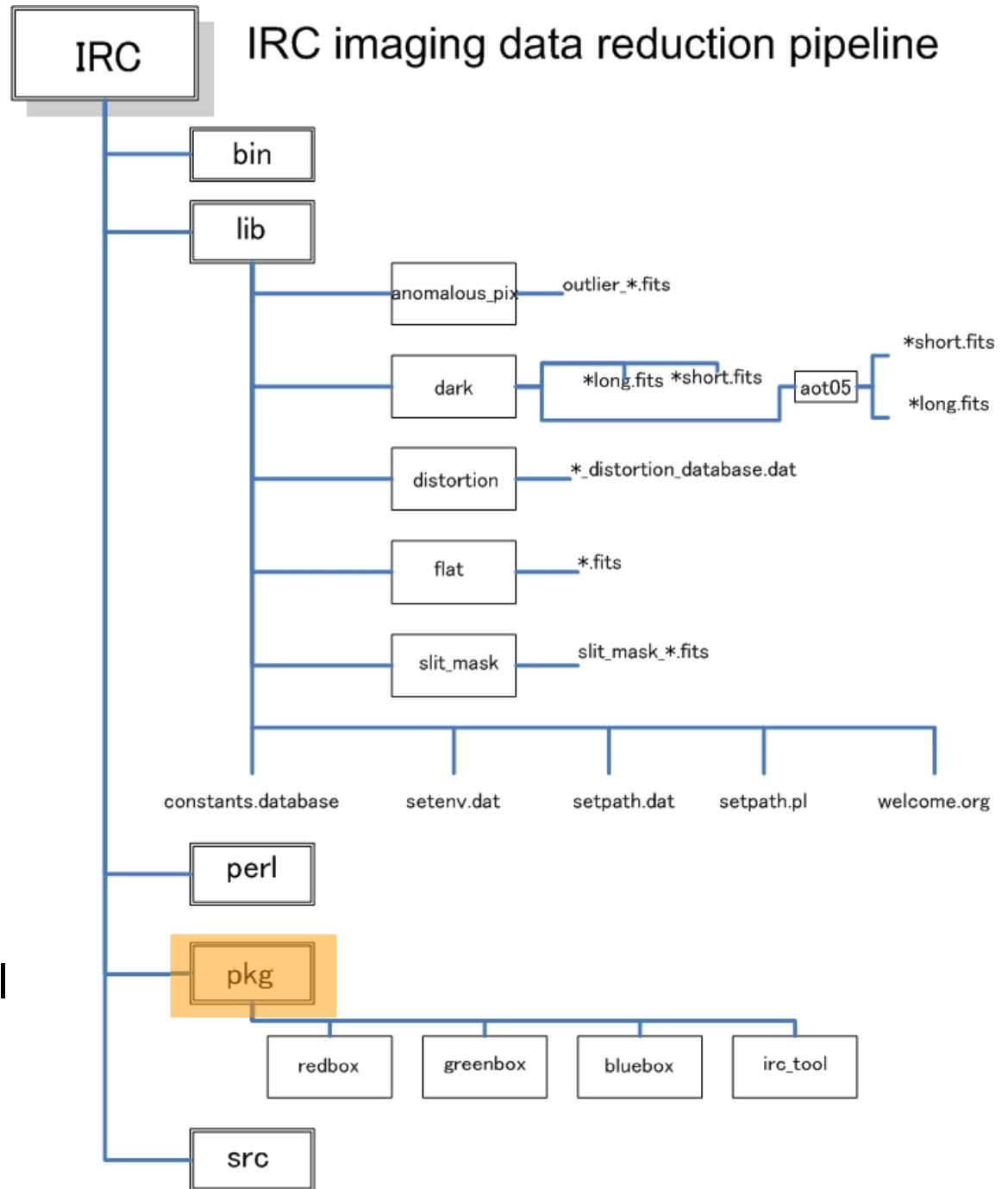
# Structure of pipeline(5)

- perl
  - perl scripts used in pipeline



# Structure of pipeline(6)

- pkg
  - redbox
  - prepipeline
  - greenbox
  - pipeline
  - bluebox
  - pipeline (coadd)
  - putwcs.cl
- irc\_tool
  - coaddUsingS.cl



# Structure of pipeline(7)

- src
  - source files to make binary files in irc/bin.
  - written in C.

